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ABSTRACT

This publication is one in a series of 12 giving the recommendations that were made for a broad and balanced education program in science for young people. This guide aims to raise key issues about assessment; provides a measure of up-dating with regard to development; encourages science teachers and departments to reflect on their current practice; and is based on the belief that there is a need to change the emphasis towards formative, criterion-referenced assessment with greater involvement of the young person. Section one deals with overview groups, overt and implied assessment groups, and the total package groups. Section two considers GCSE, grade related criteria, achievement, graded assessment, accreditation, and assessment of practical work. Section three presents learning about assessment and section four gives recommendations. An introduction, a glossary, additional readings, references, appendices on graded assessment in science schemes, and pre-vocational and other developments are also provided. (RT)

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SECONDARY SCIENCE CURRICULUM REVIEW

SSCR

BETTER SCIENCE: Assessing progress

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Curriculum Guides

SECONDARY SCIENCE CURRICULUM REVIEW

SSCR

BETTER SCIENCE:

Assessing progress

Curriculum Guide 11

Compiled by Cathy Wilson

Heinemann Educational Books/Association for Science Education
for the School Curriculum Development Committee

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This Guide draws on the work of a large number of SSCR groups whose contributions are acknowledged in the text.

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Foreword

This is the eleventh in a collection of twelve Curriculum Guides from the Secondary Science Curriculum Review, published jointly by Heinemann Educational Books and the Association for Science Education.

A *Directory of Resources* and a book, *Better Science: Making it happen*, which tries to set the Review's recommendations in the context of the whole school, will appear at the same time as the Guides. These will, when taken with earlier and forthcoming SSCR publications, including those from local groups, constitute the recommendations which the Review is making towards a broad and balanced science education for all the young people in our schools. The series title 'Better Science', is thus both apposite and self-explanatory. It is hoped that the current phase of the Review (1986–89) will achieve successful implementation of the recommendations.

But what is the status of these new publications apart from reflecting the formal approval and support of our major sponsors, the School Curriculum Development Committee and the Association for Science Education? From what sources have the recommendations within them emanated? Those readers unfamiliar with the history of the SSCR will find it explained within the Guides; but most will be aware that it set out as a project which tried fully to involve the practising teacher in the development of solutions to the problem of science for all. Thus, although the Guides have been compiled principally by the Central Team of the Review, they draw on the work of thousands of teachers in working groups over the past four years. Although the work of many of the groups is referred to in the Guides, it is not possible to refer to it all. In the *Directory of Resources* readers will find details of what many of these groups have produced. The writing of these Guides, however, would not have been possible without the groups' existence and the Review Central Team hopes that the content of the Guides truly reflects their work. Thus the pronoun 'we', used within them, often reflects the view, gleaned over five years of consultation, of the practising teachers involved with the Review. On other occasions it can represent the views of the SSCR as constituted by the Central Team and Steering Committee and it is hoped that particular usage will be apparent from the context.

Jeff Kirkham
Mick Michell
Jeff Thompson
Dick West
(SSCR Curriculum Guide Editors)

Introduction

'No he can't come out until he's finished his marking . . .'

In producing this report on assessment our aim has been to write for our fellow science teachers. What we have tried to do is raise some of the key issues relating to assessment in science and provide a measure of updating, both in terms of the development work undertaken by Secondary Science Curriculum Review groups and of national developments in formal examining. By this means we hope to cause teachers (particularly teachers of science) to reflect on current practice, both individually and in departments, with a view to bringing about some change in the strategies currently adopted.

We cannot claim that our report provides an exhaustive coverage or that we have been able to include all the very latest developments in the field. We are very much aware that the rate of change in this area of education is such that our words will be dated as soon as they leave the pen (or word processor). Similarly, we cannot claim to offer solutions to the many problems that science teachers currently face in introducing unfamiliar assessment techniques. However, we will refer readers, where appropriate, to texts that will provide more detailed information or a deeper coverage of some of the more technical aspects of assessment.

The teaching profession faces many challenges (and problems) at the present time, not only in the field of assessment. As science teachers we are being asked to revise teaching strategies and also to review syllabus content with an eye to reduction, whilst introducing more that is technologically, economically and environmentally relevant. Most importantly, we are being encouraged to reorganise the curriculum so that balanced science schemes are available to all. We are asked to teach across a broader range of subjects and be aware of the differing needs of children in terms of their gender and cultural background as well as their perceived abilities. There are yet further demands consequent upon developments in the teaching of science in primary and middle schools which mean that we need to tailor our secondary courses accordingly. All these changes are required at a time of very limited financial, and thus material, resources and of declining numbers entering the profession to teach the physical sciences. Yet these very changes are making more and more demands on teachers' resourcefulness and time. We are being asked also to be 'more accountable' to ourselves, to our colleagues, to parents, to our employers and to those employers who will recruit from the youngsters within our charge.

As already noted above, this Curriculum Guide is written at a time of unprecedented developments in the field of assessment, both in terms of the sheer number of new schemes being introduced (GCSE, with grade related criteria to follow, graded assessments, CPVE, AS levels, profiling, records of achievement, and the schemes of assessment which will relate to the National Vocational Qualification) and in terms of the magnitude and implications of some of the changes that these new schemes represent. First and foremost in many teachers' minds at present is the introduction of GCSE, with its demands for more course work assessment and the regular assessment of practical work.

Where does the Review stand in all this? In the paper written by the Central Team in 1984 (**0.1**) to promote discussion of assessment issues generally and with specific relation to science, three premises fundamental to the thinking of the Central Team were clearly stated. It is our view that the essence of these needs to be repeated at the start of this second document on assessment, not least because they represent a philosophy that has been accepted, consciously or subconsciously, by the majority of the Review groups working in this area.

1 Assessment should play a formative part in a coherent educative process (and not be regarded as merely summative).
2 For assessment to be formative, the results have to be available to the learners in a form which encourages them to work towards improvement of performance.
3 Assessment, whether for formative or summative purposes, should be appropriate to the full ability range.

However, as befits the end of one phase of the Review, when there is a need not only to reflect but also to look forward, we would argue in favour of yet further change in both the purposes and processes of assessment. Whilst we accept that the major purposes are

to inform the student,
to inform the teacher (and colleagues), and
to inform the outside world,

we believe there should be a continuing review of the emphases of the assessment strategies that we employ. With this in mind we would like to pose a number of questions for the reader.

1 Are you maximising the potential of *formative* assessment by employing it systematically and using the outcome for *diagnostic* purposes, both with regard to the progress of the students and in an evaluation of your programme and teaching styles?
2 When *summative* assessment is necessary, are your objectives clear? Do you employ a range of techniques that will enable a spectrum of skills and processes to be tested, giving opportunities for *all* students to show what they can do?
3 Is there good articulation between your *formative* and *summative* assessment strategies?
4 Are you using an analysis of your teaching and the students' learning when constructing a formative assessment scheme? Are you devising tests that are referenced to appropriate criteria?
5 When using a *criterion-referenced* system of assessment in preference to one that is *norm-referenced*, are you aware of the difficulties of selecting unambiguous criteria?
6 Are you giving your students opportunites to be actively involved in the assessment process, for instance allowing them to suggest when they are ready for assessment or to negotiate on the level of test to be attempted?

We believe there is a need to incorporate more formative assessment, to employ better summative assessment, to move towards criterion-referenced assessment while being aware of its disadvantages and of the times when norm-referenced assessment is more appropriate, and to move away from a system that is entirely teacher controlled towards one which involves the student in active participation and negotiation with the teacher.

For some, the changes required may not be major. As teachers we have always been involved in making assessments (both formative and summative) of a student's effort and quality of work. What we are saying is that there is a need to be more explicit about the purpose of the assessment. It is not just about identification of learning difficulties or difficult topics, or the provision of information for setting! We need to be sure that our purposes are clear to the student, to colleagues, to parents and to other users of the outcome of the assessment, and that they are consistent with our philosophy for science education. We emphasise the need to plan the assessment carefully so that it matches the aims of the course, the teaching and learning strategies employed, and the abilities and aspirations of those following it. There is evidence, admittedly based on a small survey (**0.2**), that few school science departments' plans include a detailed and systematic assessment scheme.

It should also be stressed that the information coming from the assessment scheme must be used in a positive way to make decisions about the student and her/his learning, about the appropriateness of the teaching programme and about the teaching strategies being employed. Formative assessment schemes should be constructed so that they give the youngsters positive feedback and a feeling of success that will motivate them to continue their studies. Summative assessment should move in the direction of establishing what the youngsters can do, rather than what they cannot do. Instead of comparing a young person's achievement to the standard of performance of others in the group, the achievement should be recorded in terms of the level of understanding or performance that has been reached. If the student is central to the assessment process, as we believe should be the case, then we must help each student to see her/his progress in terms of clearly defined standards that are fully understood by her/him. Also, these standards should be constructed in such a way that progress, even though limited in absolute terms, is nevertheless apparent and rewarded. In both formative and summative assessment, we need to provide real opportunities for youngsters of all abilities to apply the knowledge and skills that they have acquired.

Perhaps the move towards more active student involvement is that which will cause most concern among readers. However, we would argue that the development in a youngster of the skill of self-assessment will have longer-lasting value than all the other outcomes of assessment, both diagnostic and predictive, that we currently use. We would also argue that increased student involvement in assessment, including self-assessment, is justified because of the motivation it elicits. We also believe that it brings about increased commitment by the student, willingness to accept failure, readiness to persevere and self-confidence in learning. These are all qualities listed in *Improving Secondary Schools* (**0.3**), achievement aspect IV, with which we have great sympathy.

> *This aspect of achievement involves motivation and commitment; the willingness to accept failure without destructive consequences; the*

readiness to persevere; the self-confidence to learn in spite of the difficulty of the task. Such motivation is often regarded as a prerequisite to achievement, rather than as an achievement in itself. We do not deny motivation is a prerequisite to the other three aspects of achievement, but we also believe that it can be regarded as an achievement in its own right. For some pupils come to their schools without such motivation, yet the school succeeds in generating it in them and, in such circumstances, both the school and the pupils have made an important achievement. By contrast, some schools actively reduce the motivation and commitment of pupils, thereby causing further underachievement in aspects I-III. *In one sense, aspect* IV *is the most important of all, since without it achievement in the other three aspects is likely to be very limited, both at school and in the future. Working class pupils are particularly vulnerable here, since some of them, because of disadvantaged circumstances, come to school with already low levels of aspect* IV *achievement; they rely on teachers, in a way that most middle class pupils do not, for immediate and basic help with aspect* IV. *If the school does not attend to aspect* IV *as a central feature of its work, then achievement in the other three aspects becomes improbable. When the school believes it is not within its powers to influence aspect* IV, *the teachers begin to explain the lack of achievement in terms of the pupils' background, and these low teacher expectations become self-fulfilling. And when pupils experience their schooling as a threat to their aspect* IV *achievement, it becomes natural for them to play truant or to protect themselves by classroom misbehaviour.*

In the sections that follow, we will outline some of the developmental work being undertaken by SSCR working groups. We will consider other developments in assessment that are pertinent to the Review, and accepting that written tests and formal examinations will form a part of the assessment programme for many years to come, we include a contribution from a chief examiner. An overview section lists key recommendations as a further stimulus to discussion and the formation of policy.

SECTION ONE

SSCR developments

Much that is said or written about *assessment in science* is, in fact, concerned primarily with assessment, with the practices and strategies then related to the science context. This is an 'accusation' that could be levelled at elements of this Curriculum Guide. However, in this section we focus on the work of SSCR development groups who have taken the science curriculum as their starting point, and have developed assessment strategies to meet their teaching and learning objectives.

In aiming to give the reader some impression of the nature of the development work that has been undertaken by Review working groups, we immediately run into a problem of how to classify the information so that it does not become just a catalogue. It can be argued that many of the groups worked on assessment issues. This is hardly surprising since the criteria for development work indicated that it should 'incorporate proposals for the evaluation and assessment of learning outcomes and for reporting assessments to students, teachers, parents, etc.' To try to categorise the work according to its degree of match to the principles espoused in the Introduction to this Curriculum Guide produces very broad and overlapping categories. To attempt to match it to other aspects of development work in assessment, such as those described in the following section (GCSE, graded tests, profiling, etc.) leaves some categories empty and some SSCR work without a category to which it can be ascribed. To undertake a form of classification according to age of student appeared to have some potential but proved unsatisfactory. Thus we have settled on the following four headings: Overview Groups (those groups that have acted as a service agency to others concentrating on curriculum issues), Overt Assessment Groups (those concerned with the development of a particular assessment technique), Implied Assessment Groups (those that have made the development of appropriate assessment strategies an integral part of their development work), and Total Package Groups (those that have attempted to develop a full course with a comprehensive programme of assessment). Within these categories some breakdown is undertaken where relevant, according to the age groups and special interests that are catered for.

We cannot claim that all the assessment work undertaken by the Review is included in this section, nor is what follows a complete examination of what has been attempted and achieved. However, it is intended to show the way in which SSCR work fits in with some of the developments external to the Review and, more importantly, how it matches the principles expressed earlier.

Overview groups

If you are looking to review your assessment policy generally or to consider afresh the role of assessment in the teaching and learning of science, then attention to the work of two groups in particular is warranted. Each aims to provide general assessment guidance. In one instance the guidance, although produced by practising teachers, does not appear to have the added conviction which would have resulted from operation of the strategies in the classroom, but, nevertheless, each is worthy of consideration.

An Assessment Strategy (**1.1**) reflects the view that assessment, if it is to be valid, should

- involve the student as an active partner,
- be both formative and summative,
- act as a motivator for both able and less able students,
- reflect the total nature of science, and
- be as concerned with evaluating the curriculum and teaching methods as with measuring the achievement of the student.

The report sets out fundamental criteria for the development of an assessment strategy, including attitude assessment. The comments on assessment of process skills and the explorative dimension draw on the work undertaken by the ILEA Graded Assessments in Science Project (see Section Three and Appendix I). The report emphasises the need for the details of any assessment scheme to be agreed jointly by all staff involved before the course, module or topic is started. There is guidance on the development of a student profile which has diagnostic potential, indicates progress as well as achievement and can be used for curriculum evaluation purposes. The importance of not overburdening the teacher with recording procedures is acknowledged.

Assessment of Science Process: A Criterion-based Approach (**1.2**), considers the purposes of assessment, the nature of science, and the processes by which scientific 'knowledge' is built up in practical activities in a laboratory or in field work. Based on these factors, a criterion-based approach for assessing science skills is proposed. The criteria selected are broadly based so that they are applicable to any branch of science and to a wide range of students in terms of both age and ability. The strength of this particular report is that it not only attempts to identify what constitutes performing a skill well, but also illustrates the principles by reference to problem-solving activities which might represent either class work or course work tests. Implications for teaching are considered, as are methods of recording achievement.

A Report on the Assessment of Practical Skills (**1.3**), is the outcome of a survey of different approaches to the assessment of practical skills. The work predated the development of many GCSE schemes, so the comparative study of the approach of examination boards to the assessment of practical skills is based on CSE and GCE. (This is nevertheless useful as it identifies some good practice). Wide variations in practice and levels of guidance among the boards are revealed – variations which have by no means been eliminated, although they appear to have been reduced, in the subsequent development of GCSE practical assessment schemes. Reviews of the Assessment of Performance Unit (APU) science reports for teachers which refer to practical work, and of the Techniques for the Assessment of Practical Skills (TAPS) material (Foundation Level only) are included in the report.

Overt assessment groups

These groups were concerned with the development of a particular assessment technique.

Four main categories of development work are included here. Of the groups whose work focussed primarily on the development of general assessment schemes or techniques (which might be adapted for use with a range of courses and in a variety of contexts), there has been particular interest in *profiling* (not simply in terms of the manner of recording the outcome of assessment, but in terms of what is to be assessed and how), and in *assessment of practical skills*. The third and fourth categories were each considered by a single group only. One gave specific consideration to *assessment of skills and attitudes* as a service to curriculum development groups in the area. The other has developed an *oral assessment* scheme as a component both of course work assessment and of final assessment for a GCSE submission.

Profiling

Development work which has student profiling as its main focus has been undertaken in Berkshire, Hereford and Worcester, and Hampshire. *Pupil Profiling in Science* (**1.4**), describes the Berkshire initiative involving the development of a profiling scheme to be used with the full ability range of 11–16 year olds. The focus is on scientific skills

and processes. It is designed for use in recording the outcomes of criterion-referenced assessments. It is argued that such a profile is a more powerful and sensitive tool for pin-pointing weaknesses and strengths, and monitoring progress than is the mark book.(There are people who feel that the mark book has equal potential in this respect, but all too frequently, in practice, entries in a mark book represent the outcome of assessment conducted in a subjective manner without reference to clearly stated criteria and not related to a systematic assessment programme). The main interest is in profiling for diagnostic purposes, but the profile has been found useful in the preparation of references and it is now a part of the assessment/recording package for a proposed GCSE Mode 3 combined science scheme. The Berkshire scheme also appears to match well with that developed for use with the Associated Examining Board (AEB) *Basic Skill Tests in Science* (**1.5**).

After discussion and periods of testing pilot profiling schemes, six skill areas considered to be common to all science courses have finally been agreed and grade descriptors have been prepared according to a five point scale. These are expressed in positive terms only and represent very general definitions of skills development, as it was the intention that teachers within a department should meet at the start of a course, year or module to clarify and expand the grade criteria so as to be appropriate for their students and their specific course. (This appears to contrast with the approach recommended in *A Pilot Scheme for Profiling* (**1.6**) with its development of a profile with specific items and with course and profile developed together.) The Berkshire group recognised the need for moderation if the profiling scheme was to have validity beyond an individual classroom, so videotapes of children engaged in practical activities were made for use in in-service training and for standardisation purposes.

The most significant differences between the Hereford and Worcester scheme and that developed in Berkshire (apart from the age range for which it caters, 13+, and the selection of skills to be assessed), are that the former places great stress on the fact that teacher and student jointly complete the entries and that it operates with a much greater number of sub-divisions within the skill areas. Also, the Hereford and Worcester group felt very strongly that a successful profile could only be achieved if it was fully integrated into the context in which it was used. (In fact the two modes of development are not as divergent as they might at first appear.) The summative aspect of the profile is played down, as it is considered that the process of developing the profile, with the students being encouraged to see their own role and responsibilities in the learning and teaching process, is of far greater importance than the outcome. Development work is continuing in both these schemes and in that of the Hampshire profiling group.

Assessment of practical skills

The practical skills assessment work comes together neatly as all the groups which have focussed on this aspect have favoured the 'atomistic' approach (see the section on assessment of practical work, page 15) with the development of tests of single skills. A variety of age and ability ranges are catered for. *Warwick Assessment of Science Practical Skills* (WASPS) (**1.7**) was originally designed for second year secondary pupils but is adaptable for use in other years. The assessments have been devised with a 'fun' element appropriate to the time of year when the first assessment is undertaken. For example, at the Christmas end of the autumn term, a fairy lights circuit board experiment is used for assessing skills in following instructions, with parcel wrapping for testing manipulative skills. The intention is that such assessments should form a bridge between primary school practice and the more formal approach that might be required for GCSE. (This is one of the few groups that has considered any form of matching or bridging of primary and secondary practice.) Five skill areas are assessed and marked on a can/cannot do basis. Eighty per cent of test items, it is estimated, should be within the capability of eighty per cent of the ability range. Another very positive feature of the scheme is that it is manageable with class sizes of up to 34 – an unfortunate necessity at the present time.

Groups in Kent, Wolverhampton and Solihull have also developed schemes. *Ashford Practical Assessments in Science* (**1.8**) are designed for the 11–14 age range, starting with three skill areas (and criterion-referenced testing at three levels). They do not, it is claimed, make unreasonable demands on resources. The assessment scheme can be linked to a computer program which facilitates the storage of results and issue of certificates. A video for briefing purposes is included. Other Kent groups have been working on similar developments with different age groups. The Solihull scheme is devised for less able students in the 14–16 age group and consists of a set of post-unit tests, both written and practical, with associated mark schemes. They have been used with a Mode 3, CSE *Science at Work* scheme in the past and the new assessment proposals are linked to GCSE criteria.

Assessment of skills and attitudes

The skills and attitudes assessment work (**1.9**) is still in a developmental stage. The skills list has been agreed and includes some which are specific

to work in science as well as others which are cross-curricular, such as personal, social and study skills. The list is not intended to be prescriptive, having been developed as a form of check-list to be used for reference purposes during a departmental curriculum review. A video (**1.9**) has been produced which will help teachers assess the development of their pupils' skills in science by direct observation as part of a normal programme of practical work. (The video includes one sequence which is not only of value from the assessment viewpoint but also for its illustration of an excellent teaching/learning situation in second year science.)

An attitudes list has also been agreed, but appropriate assessment instruments are still being developed in this area.

Oral assessment

Oral Assessment in Science (**1.10**) is a very interesting development intended to increase the scope of assessment procedures with students in the lower half of the ability range (14–16). Designed initially for use with *Science at Work* materials and a Mode 3 CSE, a limited grade GCSE submission has now been made.

Oral assessment is used in relation to the objectives covering

- communication of scientific concepts,
- the development of a comprehension of basic concepts, and
- the development of an awareness of the contribution of science to the economic and social life of the community.

The oral components count for twenty per cent of the final mark, ten per cent being for in-course assessment of oral work and ten per cent for the final oral test/interview. Examples of the interview documentation are included in the report of the group's work, along with details of the organisation and grade descriptors.

All the development work described in this section of the Curriculum Guide has formative as well as summative characteristics, in fact the emphasis is on the former, although the diagnostic feedback aspect is not perhaps as well developed as it might be. In all cases the tests are criterion-referenced with the emphasis more towards the lower end of the ability range. However, apart from the profiling schemes, the level of student negotiation/partnership in the assessment process appears to be limited.

Implied assessment groups

These groups have made the development of appropriate assessment strategies part of their work, and quite a number have taken as their main theme the teaching of science through a problem-solving approach. They have been concerned with, among other things, the development of practical skills, but this is in a holistic manner so their approach to assessment is somewhat different to those described above. Unfortunately, the extent of the descriptions, of the assessment element is rather limited in the groups' reports.

Problem-solving in science

Problem Solving in Science 11–13 (**1.11**) includes a set of twenty problems, some structured and some totally open-ended. The aims of the 'course' are very clear, which has obvious advantages in relation to the design of the assessment programme. The aim is to assess both the processes and the strategies involved in solving the problems, and to relate the quality of the solution to the youngster's ability and experience. (This nicely illustrates a point made in the Introduction about the importance in formative assessment of relating standards to pupil capability.) An essential part of the assessment is the youngster's own evaluation of the success of her/his solution, with able pupils being expected to propose modifications to their strategies. The development by the members of a class of their own criteria for the evaluation of solutions to problems is one way that has been suggested to increase the youngsters' awareness of the need to look critically at the strategies they have adopted. This process of self-assessment is an important adjunct to the assessment programme. Although not described in detail, it appears that the assessment procedures do not in any way constrain the teaching and learning strategies.

Problem Solving for the Less Able (**1.12**) provides details of eight problem-solving activities for youngsters in the 13–16 age range. Little detail of the assessement strategy is provided, but for each activity there is a self-assessment sheet to be completed by the students.

Problem Solving for the Less Able in the 14–16 Age Group (**1.13**) includes a bank of seventy problem-solving activities which have been developed and incorporated into a course leading to the Stockport Science Leaving Certificate. The assessment of course work for the certificate is entirely practically based and relates to the application of ideas and the interpretation of data as well as the basic practical skills. The course content parallels that for a proposed limited grade, GCSE Mode 3 course which has a number of innovative assessment procedures, including oral assessment. At the time of writing, the detailed assessment guides are still awaited.

Science for the less able

Reference to the Stockport Certificate as an award for the less able, or less academically-motivated,

leads on to the mention of a number of schemes where locally-validated certificates have been devised for lower-achieving pupils. The Hertfordshire Science Achievement Scheme (**1.14**), which is part of a county-wide project covering a number of subject areas, is a scheme for fourth and fifth years leading to the Hertfordshire Achievement Award in Science. The scheme emphasises the development of the practical (and social) skills and processes which are considered to be relevant to everyday life. Content is specified in the most general of terms, based on four study areas chosen to achieve a balanced science coverage. There is a close match between the skills, processes and attitudes listed and those specified in *Towards the Specification of Minimum Entitlement: Brenda and Friends* (**1.15**), but the group has experienced difficulty in devising objective tests to measure the achievement of attitudes and social skills. The assessment is thus to be reported in four ways

- objective assessment in certain skills areas,
- through teacher comment,
- through pupil comment, and
- as a result of end of module tests.

The objective assessment of practical skills is undertaken during the course of normal laboratory work, according to a criterion-referenced scheme. Development work continues, as the group is keen to include problem-solving skills in the assessment programme.

There are some similarities between the Hertfordshire scheme and that operated by Waltham Forest, *BASIS: Borough Achievement Scheme in Science* (**1.16**). This scheme contains a formative assessment programme for basic skills in years one to three, and a certificated modular course, validated by the local Chamber of Commerce, which is built on in years four and five. Assessment of the modular scheme is through successful completion of tasks within modules (both skills-oriented and written tasks). End of module tests are available but not obligatory.

The Borough Achievement Scheme is one of several described in an interim report by an Essex group which has surveyed a variety of assessment schemes which may be suitable for use with low achieving pupils. Also included in the survey are the Avon Science Achievement Project, Oxford Certificate of Educational Achievement, ILEA's, Graded Assessments in Science Project (GASP) and the assessment aspects of Science in the Secondary School Curriculum in Lancashire.

Science Think Books

Several of the schemes referred to above make reference, if only in passing, to the use of pupils' comments in the construction of the final assessment report. In this respect, group members and teachers in general would do well to consider the approach used by a Wiltshire group in encouraging youngsters to write freely about their learning in science. *Science Think Books – an introduction to their use in science lessons* (**1.17**) provides a fascinating description of a scheme in which youngsters keep science journals or logs. These 'Think Books' act as a form of private dialogue between teacher and student and are intended to serve a variety of purposes. Those of importance from the point of view of assessment and evaluation include helping the students to think about a topic with which they are having difficulty, encouraging them to comment on areas where they have not understood or feel they need to find out more, and providing each student (and the teacher) with a personal map of progress. Entries in the Think Book can be used by the student for self-diagnostic purposes at the end of a topic. However, if the students are encouraged to make entries in their books before the start of a topic, they can also be used by the teacher to assess an appropriate starting point for work. Some evaluation of a particular teaching strategy or aspect of the science curriculum may also be gleaned from entries. Clearly this approach has great potential for helping youngsters to see themselves as active participants in their learning and for emphasising that they have their own contribution to make to their assessment. Equally clearly, the system can only operate if an atmosphere of trust is developed between teacher and learner about the ways in which the books are to be used.

Total package groups

GCSE schemes

Included in this category are groups that have attempted to develop a full course and a comprehensive assessment programme. The extent to which the development of a GCSE syllabus and assessment scheme represents a full course will not be argued here. Clearly many teachers will be interested to learn of GCSE developments that represent balanced science courses and a number of these have been developed by SSCR working groups. The match between Review philosophy and the National Criteria for GCSE has not been exact, so compromises have had to be made at some stage in the development programme, but, nevertheless, some very interesting schemes have emerged. It is a pity that more credit has not been accorded by some examining groups to the role of the SSCR working groups in syllabus development.

At the time of writing, at least eight GCSE syllabuses with strong SSCR influence have been

approved. Two of these, Science (Dual Award) and Modular Science, are being offered by the Northern Examining Association. These will be taken as examples because of interesting characteristics in each case. (A list and brief analysis of these and other syllabuses representing balanced science schemes which occupy twenty per cent of curriculum time were published in *Education in Science* in January 1986 (**1.18**)). The Association for Science Education has recently set up a working party to report on these schemes in more detail and to evaluate both the syllabuses and their assessment schemes according to the criteria for balanced science programmes implicitly stated in *Education through Science* (**1.19**).

The Northern Examining Association's Science (Dual Award) scheme (**1.20**) has a strong skills/process orientation but establishes a sufficiently strong concept base on which to build further studies in science. All being well, it will lead to two distinct awards, Science Principles and Science Applications, representing two different aspects of scientific work. Science Principles is concerned with investigating and establishing science concepts, while Science Applications involves the skills needed to understand and use these concepts. The subject matter is arranged in a way that brings together concepts from different parts of the science spectrum but does not impose any particular teaching order or constrain teaching strategy. In fact, it lends itself to a variety of approaches. The aim has been to restrict the knowledge base required for examination (recall) purposes. It will, however, be open to the examiner to test the application of scientific principles in content areas which are not specified, but in these cases the material on which the principles are to operate will be provided and explained. The examination papers will not be set so that each leads to one particular award. Instead, a method has been devised for the allocation of marks within questions under the appropriate award heading. Interestingly, it is planned, ultimately, to achieve differentiation in the summative aspect of assessment by a combination of differentiation 'by paper' and 'by outcome'. In a system of differentiated papers, there is an attempt to match the assessment tasks within a paper to the ability range of the candidates being assessed, and choice between the papers to be attempted by the candidates is made in advance. In a system of 'differentiation by outcome', common papers contain questions through which differentiation can be achieved according to the candidates' responses. The common papers have associated mark schemes that are drawn up in anticipation of the different degrees of depth and sophistication with which a candidate will answer. This system, it is argued, reflects more effectively what candidates know and can do, with less emphasis being placed on what they have failed to communicate. The NEA Science Group is one of several that has been invited by the Secondary Examinations Council to provide evidence that common questions can be devised which can be answered with different degrees of sophistication and which will allow different levels of mastery to be recognised by the mark scheme.

One of the special features of the Modular Science scheme (**1.21**) is that, as a result of its core plus options format, it allows schools to provide a wide range of courses. Depending on the number and nature of modules studied, a single or double Science award may be achieved, or, for example, an award of Science: Core and Biological or Science: Environmental and Technological.

Schools may also offer their own option modules on a Mode 3 basis. Perhaps the most interesting aspect of this scheme is the alternative assessment model which has been used to accommodate two different teaching and learning approaches. In each case, end of module tests, which may be set by the school or the examining association, are used to test knowledge, understanding and application. In one alternative, information handling, interpretation and evaluation are assessed at the end of the course by a written paper which is independent of the modules studied, while practical skills are assessed through course work. In the second scheme, devised particularly with TVEI courses in mind, all these skills are assessed through course work, but there is also a unifying module with appropriate assessment which replaces an option module. This module and its assessment, represent a test of the whole range of skills, knowledge and understanding developed throughout the course.

The Co-ordinated Science Project (**1.22**) represents a major piece of development work. The outcome is a three year, double certificate science course consisting of thirty-six units, and a quite innovative approach to assessment has been planned. It is based on the philosophies that

- achievement of all objectives of the course should be assessed,
- assessment should have a positive effect on learning,
- achievement should be rewarded as it occurs,
- assessment should be formative and summative,
- assessment should be an integrated part of teaching and learning, as far as is possible, and
- tests should be criterion-referenced.

The formative aspect of assessment is used in the Suffolk Record of Pupil Achievement, while the summative assessment is matched to a dual

award GCSE scheme. There are three levels of achievement (Foundation, Standard and Special) indicating attainment in each of the units.

Three types of assessment are used:

(a) 'can do' tests (marked on a yes/no basis)
(b) unit tests, which are differentiated written tests matched to the pupil and the learning task and based on an 80/80 model. (80/80 tests are designed so that at least eighty per cent of pupils get eighty per cent of the answers correct.)
(c) criterion matching (suitable for the assessment of six of the eight process skills that have been identified and which will be developed within the course).

The process skills identified cover knowledge, understanding and application, a range of practical skills and some social skills.

Assessment will be carried out

(a) by the science department within a school,
(b) through collaboration between groups of schools, and
(c) in collaboration with the GCSE examining group.

At the time of writing, further work on the assessment of attitudes is planned.

Science for non-certificate pupils

A similarly ambitious piece of development work has been undertaken in Cheshire. This has led to the establishment of CHASSIS (Cheshire Achievement of Scientific Skills in Schools). It is a curriculum and assessment scheme in science for the lower forty per cent of the ability range. Although designed on the basis that all students will spend twenty per cent of their time in years four and five on the study of science, it can be adapted to suit a smaller commitment to science, with an appropriate reduction in content. (The certificate is then modified accordingly.) The twenty per cent version of the 'syllabus' covers thirty concepts and eight skill areas and lends itself to a number of curriculum structures. In teaching and content terms it matches with the Mode 3 CSE courses that have been in use in the county. The difference is in the manner of assessment. Formative, short-term, rewarding assessments are used, which test mastery of skills only and give ample opportunities for repeat tests. The tests are administered on an individual, small group or class circus basis. Marking is undertaken mainly in relation to the outcome of the tests. A full report covering the development work and the philosophy of the scheme is contained in the *CHASSIS Teachers' Handbook* (**1.23**). Supplementary test items are planned for the future.

Of the many other full schemes that have been devised, one of particular note, because of its assessment strategy, is still in the process of development. It should perhaps have been included in a different category, as the main focus is on the assessment, but it is linked to a curriculum scheme. The work is being carried out in West Glamorgan. The assessment scheme is based on the philosophy that assessment can play a far more dynamic role in the learning process than it currently does. Teachers already spend much of their time carrying out assessment, but in such a way that much of the information obtained about pupils' skills, qualities and weaknesses is generally inaccessible. The West Glamorgan project has been concerned with modifying existing practices to provide a longitudinal record of attainment and experiences. Particular emphasis is placed on the students themselves diagnosing their own strengths and weaknesses and developing their own profiles. This is perhaps one of the best examples in the Review of active involvement by students in the assessment process.

In conclusion, it is clear that the catalogue of SSCR development work in the field of assessment is impressive both in range and depth of treatment. However, an area which has received limited attention is that relating to the interfaces of primary with secondary education and of secondary with tertiary. Perhaps all that needs to be said is that secondary teachers have much to learn from their colleagues in these other sectors.

One item of development work which has not been mentioned in any of the above categories is that of the Oxfordshire group. It might have been included in the Overview Group category but perhaps comes well at the end. *Reviewing Practice in the 11–13 Science Curriculum: Assessment* (**1.24**) is one of a series of four INSET guides and contains a number of starting points for discussion and planning, by an individual teacher, by a whole department or by a group of teachers from several schools. If new assessment methods are to be introduced, this should not be done on an individual teacher basis, although there is no reason why an individual should not initiate discussion. The questions raised in the Oxfordshire book should prove helpful in this respect. Another good reason for including the Oxfordshire work in this concluding paragraph is its emphasis on the point that, however willing we are to explore new strategies, support is needed. Thorough exploration of new schemes takes time and is aided by both an input of ideas from external sources and by cross-fertilisation of ideas between groups or individuals tackling similar problems. Also, implementation is likely to be more effective if there is a source of external support and expertise upon which to draw. Appropriate in-service education is one very important way in which this vital support can be provided.

SECTION TWO

Current developments

GCSE

Having explored much of the development work of the Review in the area of assessment in science, we turn now to contemporary developments in examining and assessment. These are considered from the standpoint of the Review, with its prime concern for curriculum development served by appropriate assessment strategies.

At the time of writing, it is the GCSE which is at the forefront of most teachers' minds. Clearly, the GCSE will bring about both curriculum reform, as all external examinations do, and reform of assessment strategies. It is sensible, therefore, to indicate the benefits that GCSE has to offer. Although we believe that assessment ought to be the servant of the curriculum, it has to be acknowledged that it may be some time before this ideal is followed in practice. Some of the more innovative GCSE syllabuses and assessment schemes in science will do much to underpin good curriculum practice in a public way and advance the acceptance of broad, balanced science programmes to 16+. We therefore welcome those changes brought about by the introduction of GCSE which match our hopes for the curriculum. However, it is unfortunate that the hurried manner in which it is being introduced may mean that the positive effects are not as immediately apparent as they would otherwise have been. The reader is encouraged to study the aims of the Review as identified in *Science Education 11–16: Proposals for Action and Consultation* (**2.1**) and to compare and contrast these carefully with the aims and assessment objectives of the *GCSE National Criteria: Science* (**2.2**).

The GCSE criteria place emphasis on the balance of assessment methods, recommending a variety of styles of written question and of other instruments, but imposing some contraints on the parts that each might play. Tests of recall are to be less dominant and new emphasis is to be placed on practical skills and processes, with not less than twenty per cent of the marks being allocated to experimental and other practical skills. Assessment of other forms of course work is also encouraged but not required. At least fifteen per cent of the total marks are to be allocated to assessments relating to technological applications and social, economic and environmental issues. Assessment by oral examination is not encouraged, although its use in very limited circumstances is not ruled out. It is hoped that the changes which the criteria represent will lead to a better articulation between curriculum and examinations and the acquisition of a wider range of skills by teachers in general.

On the less positive side, the need to reduce the overall amount of factual knowledge required, as called for in *Science 5–16: A Statement of Policy* (**2.3**), does not appear to have been met as well as it might. All the Grade Related Criteria working parties for the sciences (whose work will be described more fully in the next Section) have stressed the need for reasonable limits to be set on the content of syllabuses if an improvement in the students' abilities in the skills and processes of science is to be achieved. Furthermore, there is a degree of mismatch between the development of criteria for each of the individual sciences – biology, chemistry and physics – and the required move towards balanced science courses which take not more than twenty per cent of curriculum time. In this respect it is encouraging to learn that the Secondary Examinations Council and the Joint Council for GCSE are now working on a strategy which will develop criteria for the selection of content in science, particularly for double award science schemes.

Another aspect of implementation of GCSE which will concern some teachers is the fact that there are likely to be fewer Mode 3 examinations and thus a temporary reduction in the number of individualised, custom-built courses. That is not to say that custom-built courses are necessarily richer than Mode 1 courses, as much depends on the skill of the builder, but it does represent a difference between the Review, with its encouragement of development work to match 'local' needs, and the GCSE in the early years of its implementation.

Before leaving the subject of GCSE, we sound a gentle word of warning concerning the tensions between assessment schemes that are primarily summative and the development of good practice in formative assessment. Whilst it is recognised that course work assessment is a requirement of all GCSE schemes, in many of the approved science proposals this element is entirely taken up with the assessment of practical skills. Furthermore, the extent to which the course work assessment will be used for diagnostic purposes is as yet unknown. In the report *Assessment Purposes: A Study of the Relationship between Diagnostic Assessment and Summative Assessment for Certification* (**2.4**), there is an interesting account of the introduction of the Standard Grade

Examination in Scotland. It highlights the limiting effect, in terms of diagnostic potential, of the slavish copying by teachers of the external examination procedures as a result of their anxiety to prepare students for the final examination.

Grade related criteria

If the GCSE examination is to demonstrate what youngsters can do across a range of skills and processes, it is essential that the outcome of the assessment is made available to subsequent users of the qualification (such as employers) in a way that is both informative and meaningful. The need for a greater degree of criterion referencing in order to achieve a clearer definition of the levels of knowledge and performance expected from candidates for the award of particular grades, was somewhat cautiously referred to in *Examinations at 16+: A Statement of Policy* (DES) (**2.5**). Subsequently the SEC has set up a number of working parties to develop criteria for the award of grades. The separate subject science working parties, which were set up first, produced draft reports in the autumn of 1985 and the Science working party, set up later, reported in the summer of 1986. The proposals of the working parties for the separate science subjects share a common structure in that they have three different domains for assessment, each domain being 'a collection of elements that forms some reasonably coherent subset of the skills and competences needed in the subject'. In accepting the three domains 'Knowledge with Understanding', 'Handling Information and Solving Problems' and 'Experimental Skills and Investigations', the three science groups felt that the distinctive features of their own subject could be retained through the emphasis given to particular science processes and through the aspects of the content and the range of contexts in which the skills were deployed. They also agreed on an equal weighting across the domains.

The Science working party report also proposes three domains, but with a sharper definition of the boundaries between them. The first domain is thus simply 'Knowledge' (assessment of understanding, it is argued, cannot be confined to one domain), while the third is entitled 'Practical Enquiry'. The second domain is as that of the separate science working parties. As pointed out in the *GCSE Guide for Teachers: Science* (**2.6**), the terms 'experimental' and 'practical' are often used in an interchangeable manner, although some aspects of experimental work are not practical and practical skills can be displayed in other than an experimental context. To some extent, this argument is reflected in the distinction between the 'Handling Information and Solving Problems' domain and the 'Practical Enquiry' domain of the Science working party report, with assessment in the latter domain related to a student's own practical work, while assessment in the former is confined to skills that can be brought to bear upon other experimental information. Having reduced the scope of the first and third domains, the Science working party recommends that performance in the second domain, 'Handling Information and Problem Solving', should carry a greater weighting than that in either of the other two.

Agreement about domains (and it has not yet been achieved) is only part of the task of devising a criterion-referenced system, the main object of the exercise being to define performance levels within these domains. Success in achieving certain levels of attainment has then to be translated into grades. In this respect the working parties have introduced different schemes. In broad terms, whatever number of levels is agreed, these range from the minimum that is commensurate with positive achievement, to the maximum expected for GCSE in the subject in question. However, such broad descriptions are clearly not sufficient, and, in order to make them operational, the criteria for different levels of performance have been spelt out in considerable detail, and in a variety of ways, across all four reports. Variety is also apparent in the assessment methods suggested for measuring levels of achievement across the domains and across subjects. In-school appraisal will allow more opportunity for assessment of extended problem-solving exercises. By these means differentiation in terms of skills development may be more easily achieved according to the context of the question and the complexity of the task.

The proposed grade criteria system is, without doubt, very complex but it is regarded by some as the most exciting and radical aspect of GCSE. Whether or not the systems recommended ever come into operation, those who have been exposed in any way to the development process will have been prompted to reflect much more critically on the aims of assessing young people and the style of reporting, and this should have beneficial effects beyond the context of GCSE.

The working parties have pointed out that radical changes are demanded by a shift towards criterion referencing and these will require considerable adaptability on the part of those involved in teaching and examining. They stress that if the changes are to achieve the hoped-for improvement, 'well-conceived and generous programmes of in-service training will be essential'. The different problems faced by external examiners and teachers in accomplishing a successful change to criterion-referenced systems of formative and summative assessment are well explored in *Assessment Purposes* (**2.4**), to which reference has already been made.

Profiling and records of achievement

The SEC Grade Criteria working parties have expressed a hope that achievements in the three domains will ultimately be reported separately. In recent years, increasing attention has been devoted to the question of how the information gained from an assessment programme can be expressed in a meaningful and helpful way. In its ten principles for science education, *Science 5-16: A Statement of Policy* **(2.3)** included 'breadth' and 'balance', referring to the main concepts across the science disciplines, to technological applications and the social consequences of science, and to the range of scientific skills and processes. As our students develop a wide variety of skills during their science education, it hardly seems logical to record the outcome of that education in terms of a single grade on a certificate at 16+. Other methods of communicating outcomes of assessment are thus being advocated and the 'profiling movement' has been growing in strength since the late 1970s.

For the purpose of this section, we will consider profiling as the process by which information about a student's involvement, performance and progress is gathered and reported. The information will relate to a range of skills and abilities within a subject or across a set of subjects, even though some may not be amenable to formal assessment. The student profile may also cover experiences of an extra-curricular nature. (The term 'record of achievement' refers to the document which gives the information in terms of levels of attainment achieved in a set of skills and abilities. This information will probably be the outcome of a formal or informal assessment programme.)

It must be stressed that while profiling gives rise to a record of achievement, it is not a method of assessment. Also, it is worth pointing out that a good record system cannot make up for a poor assessment system, and that the potential of a good assessment system, for diagnostic or summative purposes, is reduced if it is not supported by appropriate records.

Profiles can be either formative or summative, and the two may be very different in format and style, although similar in their intention of providing the user with information. A formative profile can be lengthy and detailed, although its content and style will change with the different stages of a young person's education. The profile for a primary school child will be different from that of a 16 year old. (Teachers of the early years in secondary school would be well advised to look at the profiles developed for their pupils in the feeder primary schools, both for the information they contain and for ideas for record-keeping.)

The diagram below shows different forms of profile and the ways in which they may be constructed.

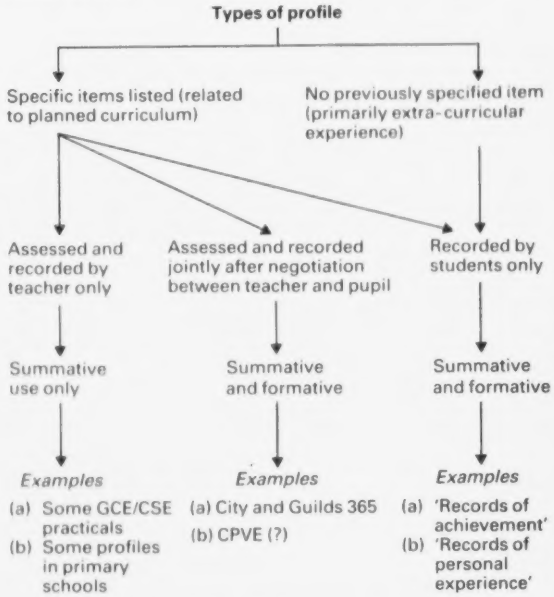

Types of profile
Specific items listed (related to planned curriculum)
No previously specified item (primarily extra-curricular experience)
Assessed and recorded by teacher only
Assessed and recorded jointly after negotiation between teacher and pupil
Recorded by students only
Summative use only
Summative and formative
Summative and formative
Examples
(a) Some GCE/CSE practicals
(b) Some profiles in primary schools
Examples
(a) City and Guilds 365
(b) CPVE (?)
Examples
(a) 'Records of achievement'
(b) 'Records of personal experience'

Fig. 1 Types of profile. This diagram is reproduced with permission of the SSCR Hereford and Worcester Profiling Group

As a formative profile is used for diagnostic purposes, it must refer to strengths *and* weaknesses, and it should indicate not only achievement but also progress. There is wide agreement, however, that a summative profile should consist only of positive statements. This is not quite as straightforward as it sounds. We know that a potential employer may read a reference for what is not there rather than for what is , and the same may well apply to a profile. How will the reader of the profile know why the particular attribute for which she or he is looking is not recorded? It could be a 'sin of omission' rather than adherence to a deliberate policy not to record a 'sin of failure'! This may be an argument in favour of having standard headings and sub-headings for all profiles.

Provision of a summative profile is a way of ensuring that as much information as possible about the student is presented under a variety of different headings and in a way that is readily interpretable to potential users. Many benefits are also claimed for a formative profiling system – increased student motivation, better pin-pointing of a student's weaknesses and strengths, development of better teaching and learning strategies, opportunities to reward qualities not recognised in current examination schemes, a rationalisation of record keeping and the realisation of a more flexible assessment framework to accommodate the new curriculum

developments. The reader will find many of the same claims being made for graded assessment schemes (see the following sub-section), but these schemes are simply one way of obtaining the information from which a profile may be compiled.

Formative profiling is not without its problems, but the effect it can have on the process of assessment and reporting should not be underestimated. Construction of profiles so that there is a true match between curriculum and assessment objectives is very time-consuming and requires a level of expertise which may only be achieved through in-service training. It can be argued that if there is to be a match between curriculum and assessment, there will be variation from school to school. Thus each school might need to develop its own profile to suit its particular needs. However, there are clear advantages in having some degree of commonality of schemes, not least in the eyes of the user. Some form of standardisation might be achieved by the use of common headings and sub-headings and common descriptors for use under those headings.

In terms of the SSCR belief in the centrality of the pupil to the assessment process, a quotation from the Dorset/SREB Assessment and Profiling Project is apposite (**2.7**).

> *Pupils can be helped to understand the educational experience and processes through which they learn. In particular, the profile can guide, shape, alert, advise and direct them in an understanding of their strengths and weaknesses and, if appropriate, the ensuing remedial programme. It should promote effective consultation and negotiation with teachers and tutors ... The profile can unite and harmonise the curriculum policies, the assessment, the recording and reporting systems and the counselling and guidance procedures.*

In the Dorset/SREB Project, one of the great benefits has been the opportunity to develop assessment objectives closely related to the new curriculum objectives, the two being developed and evaluated together. This is surely the way in which all assessment should be planned.

Graded assessment

A considerable amount of energy is currently being devoted to the development of graded assessments, graded tests and assessment of graded objectives schemes. All these are criterion-referenced systems, and similarities will be seen between the objectives of the GCSE Grade Related Criteria exercises and those of the graded assessment schemes. However, there are also differences, as might be expected since the former exercise relates primarily to summative assessment and the latter is more concerned with diagnostic formative assessment, with reward for short term mastery. This is, perhaps, an oversimplification of the issue, for GCSE, as already acknowledged, requires the assessment of course work and this can and should be used for formative purposes. Furthermore, it would be possible to employ a graded test scheme and use it for short-term summative rather than diagnostic purposes.

The graded assessment schemes in science which are available or under development include the Avon Science Achievement Scheme, the ILEA Graded Assessments in Science Project (GASP), the Oxford Certificate of Educational Achievement (OCEA), and the Midland Examining Group's Assessment of Graded Objectives in Science (AGrO) scheme.

The purposes of graded assessment

The main purpose of graded assessments is to give pupils credit for positive achievements as they progress through their education, rather than waiting until the end of the compulsory period of schooling, when, under our present examination schemes, some pupils still fail to gain any external acknowledgement of success. For those who do achieve recognition, it is in the form of a single grade only, which rarely represents effectively the outcome of up to eleven years of study. Recognition of success in itself is not the only aim for the schemes under development, which, in their various ways, aim to provide an assessment framework appropriate to the full ability range and integrated into the learning process. It is claimed that graded assessment schemes lead to enhanced motivation because of their clear identification of goals and their systems for recognising achievement on a regular basis. (The Silver and Gold Certificates of the Avon Scheme seem to have been particularly successful in this respect.) They also encourage students to reflect upon and evaluate their learning experiences and development. In some cases this is both within and outside the school curriculum. Finally, and of particular importance in the SSCR context, the graded assessment schemes provide frameworks for assessment in science, without prescribing in detail the content to be assessed, the techniques for assessment or the frequency of the assessment. Curriculum development should therefore be advanced, as the constraint of too much content and the influence of terminal examinations are reduced. Schemes can be developed to suit a variety of teaching methods and course philosophies.

Similarities between the schemes

There is not space in this Curriculum Guide to describe in full the various schemes under

development, to produce a detailed critical analysis of them, or to expound on the advantages and disadvantages of graded assessment schemes in general. However, in all cases:

- the assessments are criterion-referenced,
- the schemes are structured to provide objectives at different levels, with the lower levels being attainable by almost all at some stage in their secondary education,
- the emphasis is on process rather than content,
- a domain structure is employed (a domain is a cluster of elements of a subject forming a coherent set of skills and competences) although the number of domains varies across the schemes,
- the assessment is an integral part of learning,
- teacher–student interaction is encouraged,
- self-assessment by the student is promoted,
- a wide variety of assessment techniques is employed,
- more frequent assessment is required, although it may be spontaneous and informal,
- there is reliance on the professional judgement of the teacher and hence the introduction of the schemes should be preceded by appropriate in-service training, so that there is common interpretation of the criteria.

In most cases, the science component is not being developed in isolation. The OCEA and ILEA graded assessment schemes also cover English, modern languages and maths, while the Midland Examining Group are engaged in parallel work in these subjects as well as CDT.

Further details of the four schemes identified at the start of this sub-section can be found in Appendix I. Also included in this appendix is information about the TAPS (Techniques for the Assessment of Practical Skills) Project. This is not strictly a graded assessment scheme, but as it represents a carefully constructed system of formative assessment practice, it merits inclusion.

Schemes of accreditation

The term 'accreditation' is used in a variety of ways. For instance, accreditation may:

- refer simply to the issuing of a formal statement about a course and the student's completion of it, or
- relate to the formal recognition and approval of a course, or an element of that course, which, once approved, may be used in a variety of institutions, or,
- relate to the formal approval of an institution or centre, its procedures and provision, so that it may devise its own courses and modules according to agreed criteria and issue its own student credits.

The local education authorities in the north of England, in association with the examination boards forming the Northern Examining Association, are operating a pilot scheme which initially related to the accreditation of courses but which has been extended to the accreditation of centres.

NPRA Unit Accreditation

Although at present representatives of the NPRA (Northern Partnership for Records of Achievement) meet regularly to discuss matters of common interest with representatives of the graded assessment schemes, the Unit Accreditation Scheme of the NPRA is very different in nature. Still in a pilot stage, it has been developed to meet the short-term needs for accreditation of new courses that exist in a small number of LEAs, courses such as those developed in the Low Achieving Pupil Project and the TVEI. The scheme is designed to give recognition to work done by students who do not fit into the CSE/GCE/GCSE structure.

Basically, units of work, which may be in any area of the curriculum, are devised to meet NPRA criteria, a unit being a discrete, coherent programme of work that can be assessed. The unit might represent a very broad topic, such as astronomy, or a much narrower one such as the digestive system, but there is a requirement that the title must be meaningful to subsequent users of the letter of credit relating to the unit. The normal length of a unit in teaching time is of the order of half a term. The validation and accreditation system for the unit itself and for the method of teaching it, involves first an LEA pre-validating committee, then the regional validating committee set up by the CSE board, and then a visit to the school by a Northern Examining Association appointed assessor once the unit has been completed by the student. A report is sent by the assessor to the NEA, and provided that all is satisfactory, the NEA authorises the issuing of a statement of achievement to the student by the LEA. At the end of the course the NEA issues each student with a letter of credit listing the titles of all the units successfully completed.

The unit submission from a centre is tightly prescribed. It has to specify the curricular area(s) to which the unit relates, the learning objectives and processes involved, and the educational context in which learning will take place. It also has to specify the outcomes to be accredited in terms of:

skills demonstrated, and/or
conceptual understanding acquired, and/or
knowledge shown, and/or
processes experienced.

The ways in which these will be demonstrated and details of the school's procedures for making and recording assessments are also required.

The statement of achievement is issued in the name of the LEA (signed by the Director of Education) and lists the outcomes required for the successful completion of the unit, using the words employed in the submission. Successful completion of a unit is defined as 'achievement of each and every one of the intended outcomes listed in the submission, irrespective of the number of attempts made'. The statement does not make any reference to levels of attainment.

The first interim scheme involved only seven authorities and forty schools, but, even so, 3000 units were submitted and the validation and accreditation procedures proved to be incredibly time-consuming. A system for accrediting schools and centres, as opposed to validation of courses, which will depend on their resources, experience and ability to devise units of work, is now being piloted.

There appears to be much to commend this scheme, not least the freedom it gives to schools to develop their own courses and the availability of a system of external validation and accreditation. Participating LEAs are encouraged to disseminate information about units they have developed to reduce duplication of effort. The possibility of accreditation of schools makes the scheme even more attractive. (This was a direction in which the SSCR encouraged examination authorities to move in its earlier publication. (**0.1**)) It has to be emphasised, however, that the NPRA Record of Achievement contains no indication of level of attainment, which may affect its acceptability to some users in the early stages.

Assessment of practical work

Assessment of practical work can hardly be described as a recent development in the strict sense of the term. I can remember, despite the passage of more than a quarter of a century, the oscillating meter rule, the lens of which the focal length had to be determined, the potentiometer and sonometer 'experiments' of the physics practical examination and the quantitative and qualitative analysis questions of the chemistry practical examination. All these examinations were taken in total silence, with no teacher/student interaction beyond the occasional 'meaningful' stare from the invigilator. It represented assessment, but was it practical work in a real scientific sense?

The role of practical work in science education

Practical work in science has been viewed for many years as an important aspect of education in Britain. This is in part because it is felt that school science should reflect the nature of science as practised in the outside world, where it is accepted that all the sciences have an experimental basis and involve some form of practical activity. Practical work may also be seen as a learning process in itself. Furthermore, it is argued that practical work in science has a strong motivating influence and that it helps students by reinforcing their understanding of scientific concepts. If we are convinced by these arguments for the inclusion of practical work in our science teaching, why is it that until recently it has been given such low status in terms of assessment, and why has the stipulation that twenty per cent of the available marks in GCSE should be for the assessment of experimental and other practical skills caused such major misgivings among many members of the teaching profession? Doubtless some of the problems relate to organisational difficulties such as large class size and lack of resources including technical support. Some of the problems are related to a lack of familiarity with appropriate assessment techniques. However, there is also the fact that many people feel that some of the arguments in favour of practical work in science (as currently practised) are open to question. There is a lack of clarity in the aims and objectives involved in engaging students in practical and experimental activities, and hence a lack of clarity in the aims and objectives of assessing practical work.

The atomistic and holistic approaches

Fairbrother (**2.8**) summarises the aims and objectives of practical work in terms of wanting students to apply their knowledge and skills to solving real, live problems (acknowledging that what is real and live to one person is not so to another). He then characterises real, live problems as those that place the emphasis on autonomy in decision making and require the integration of fragments of knowledge and skills that have been learnt in other contexts. This immediately opens up one of the areas of conflict relating to practical/experimental work, that between the atomistic and holistic approaches. Those who favour the atomistic approach, aim to develop (and assess) highly specific basic skills, such as the ability to read volume in a measuring cylinder to the accuracy of one scale division or to combine small quantities of ingredients to match a given standard. Those who support the holistic approach put the emphasis on the execution of purposeful investigations, during the course of

which the necessary basic skills will be developed.

Those favouring the holistic approach argue that in concentrating on the small scale skills and only subsequently synthesising them into the whole as the atomistic approach does, the essential nature of a real scientific investigation is lost. They also question the reliability with which such small scale skills can be assessed. On the other hand, those supporting an atomistic approach argue that the ability of students to tackle a genuine investigation is hindered if they do not have some of the necessary skills already in their repertoire. They also argue that assessment on the basis of a whole investigation may not give appropriate opportunities for students to demonstrate what they know, understand, and can do. Bryce and Robertson (**2.9**) point to the fact that there is no demonstrable evidence of validity and reliability in the versions of assessment by holistic teacher-judgement which are currently available. Both 'sides', it appears, can bring APU evidence to support their causes!

To quote again from Fairbrother, the unanswered question is 'Which comes first, attempting to solve the problem, which requires a synthesis of skills, or analysing the problem into the separate skills so that they can be taught?' The answer to this question must influence the choice of assessment technique and also influence the relative weight ascribed to the different levels of skill measured in an assessment programme. The graded assessement schemes, including TAPS, tend to use the atomistic approach initially but move on from tests of small scale, basic skills to higher level, process skills and thence to investigative skills. The GCSE Criteria for Science require assessment of clusters of experimental skills which will include specific techniques and procedures but will also cover more general processes concerned with planning, investigating, recording, evaluating and interpreting, communicating conclusions and making constructive criticisms of the methods employed. It is acknowledged, however, in the *Guide for Teachers* (**2.6**) that, from time to time, there might also be a case for focussing on a single process in each task that is being assessed. The draft Grade Related Criteria report for Science (and for Physics), whilst accepting that there is some place for assessment of enabling skills, gives more weight than the National Criteria to 'complete enquiries'.

Outcome versus process

Another issue in which there is some conflict in the area of assessment of practical work is that of the relative importance of the quality of results achieved as opposed to the suitability of the procedures by which the result is achieved. It was the quality of the results which was assessed primarily in A level practicals referred to earlier, as little could be judged of the correctness of procedures from written accounts. Reliable assessment of the processes of practical work requires direct observation of performance, which may be supplemented by written accounts. Assessment of process can be undertaken on an impressionistic basis, which is inevitably subjective, or with the aid of a checklist of specific performance criteria. In the TAPS scheme, the majority of the items are assessed on the basis of the outcome of the skills task, but there are other tests which require both process and end-check assessment. Within this category, some tests require the use of a checklist, while others rely on intuitive assessment.

Formative and summative assessment

Yet another point of contention in the area of assessment of practical work is that of formative versus summative assessment. This tension affects all aspects of assessment, but is of particular concern in the practical area, where the acquisition of skills is achieved by continuous practice. Whether formative or summative assessment is used has obvious implications for the manner in which the assessment is carried out and for its timing. Formative assessment equates to diagnostic assessment and should influence subsequent teaching. It encourages the integration of assessment and instruction and relies on good teacher/pupil interaction. Summative assessment using criteria which include terms such as 'requires considerable assistance' or 'with occasional guidance' poses difficulties, as there is a conflict between the role of teacher as instructor and teacher as examiner, which may affect the interaction. The timing of summative assessment of practical work, certainly in the GCSE context, appears to cause problems for a variety of reasons and very careful planning is needed. Readers are recommended to refer to Skevington's article in *Physics Education* (**2.10**) which includes very valuable advice on the production of a summative assessment programme.

In summary, whereas we welcome the increased emphasis on the assessment of practical activities in science, it has to be acknowledged that implementation is not without its problems. As in other areas of assessment, we need to be sure that we are clear about our aims and objectives and that the schemes developed are seen by those who implement them as valid and manageable. It is important that any summative assessment does not displace the formative aspects of practical work nor must it be demotivating to the students.

Other developments

Space, or rather lack of it, dictates that developments in assessment relating to pre-vocational education, both pre-16 and post-16, cannot be covered in any detail in this report. However, a brief outline of new initiatives in this important area of education is included in Appendix II. This appendix also includes information about other post-16 initiatives such as AS levels and common cores for A level courses.

SECTION THREE

Assessment techniques

A Chief Examiner speaks: A brief discussion about summative assessment with pen and paper by Mick Michell

'I think you'll find my test results are a good indication of your abilities as a teacher!'

Preamble

We wish to put the case in this Section that summative assessment, as exemplified by end of year written tests and examinations, has suffered over a long period from a number of problems, and that these have adverse effects on the pupil/candidate. In the majority of cases (and I do not necessarily exclude the examination papers for which I have been responsible for many years!), traditional pen and paper assessment has been

threatening to the pupil,
based on insufficiently clear objectives,
used insufficiently for formative purposes,
excessively content-based.

Such criticisms apply particularly to school-based tests, which are often set under the sort of pressure which can all too easily lead to lack of care. However, we believe that public examinations, with less excuse, are often open to the same sorts of criticism. A couple of examples follow. They have been extracted from past GCE Ordinary level papers and changed in order to conceal, hopefully, their origin but not to alter their structure or sense.

Example 1

A car resting on a car jack exerts a downward force of 2.2×10^3 N on the jack. When the operating handle of the jack, which requires a force of 120 N to move it, is moved through 0.5 m, the car rises vertically by 1 cm.

(a) Calculate the work done by the operator in one downward stroke of the jack.

.....

.....(2)

(b) Calculate the work done on the car by this one stroke of the jack.

.....

.....(2)

(c) Calculate the efficiency of the jack in this instance.

.....

.....

.....

.....(2)

(d)(i) Is this machine a force multiplier or a distance multiplier?

.....

.....(1)

(ii) Explain your answer to (d) (i).

.....

.....(1)

Example 2

A black ram (male sheep) was mated with a white ewe (female sheep) and all the resulting lambs were white. A ram and ewe from this group of lambs were later mated and, of their lambs, 75% were white and 25% were black.

(a)Describe the genotype of the lambs resulting from the first mating.

.....

.....(2)

(b)Describe the genotypes of the lambs resulting from the second mating.

.....

.....

.....

.....(4)

Learning about assessment

What do such examples tell the reader? Are they indicative of a general malaise or have we chosen them specifically to support the point being made? (And just what *is* the point being made, anyway?)

We would postulate that

if written (formal) assessment is regarded as an appropriate mechanism for monitoring the progress of a group of pupils,

if the skills and processes of the area of study and its content are amenable to assessment by this method,

if the person constructing the assessment is both aware of the objectives and provided with sufficient time to construct the assessment,

if the children concerned are also aware of the objectives, feel relaxed about undergoing the assessment and know that the results will be used subsequently to assist them to improve their performance,

then there is a reasonable chance that the assessment concerned will not be subject to many of the criticisms on page 17.

However, in our experience, good assessment techniques, in any sense, are found in few schools. This is particularly true of pen and paper tests of any sort. We would argue that there are essentially three reasons for this problem:

1 Few teachers are clear enough about the real purpose of the assessment.
2 Construction of assessments has to take its place in a very busy calendar. This place is often quite low compared to the many other demands placed on the science teacher and her/his department and is lowered further as a function of the times of year when such assessments often take place.
3 Whilst all teachers are trained to teach at least one area of the curriculum, few are trained in any adequate sense to assess children's progress in it.

This Section aims to help the reader decide whether the pen and paper assessments which s/he constructs could be improved, and at what cost in personal resource. Although it is concerned primarily with summative assessment, it holds to the views espoused by *SSCR Working Paper 3* (**0.1**) and the following remarks should be regarded in such a context.

Test construction

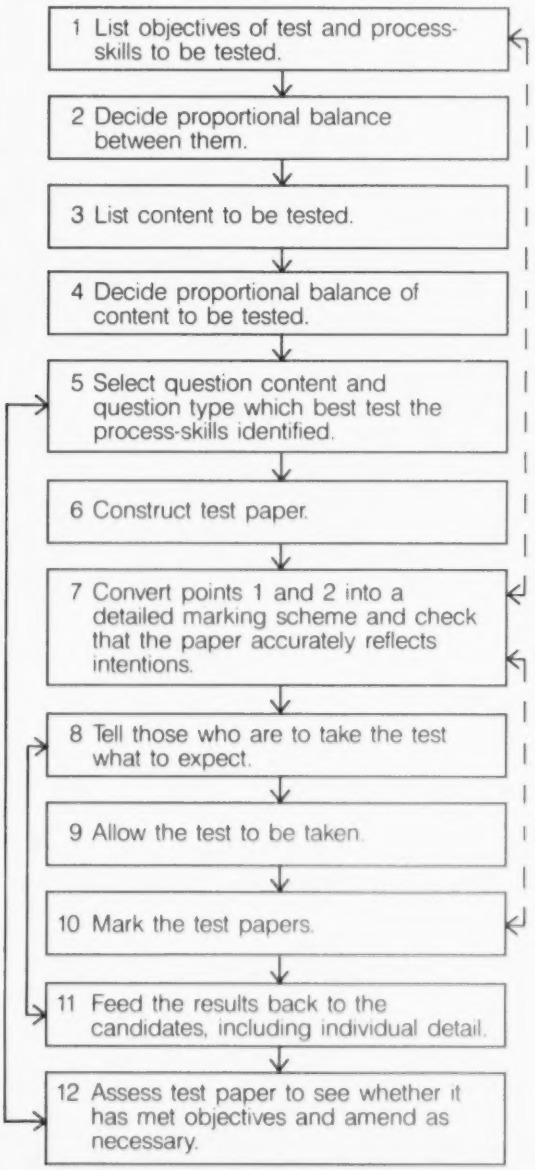
We consider that it is quite possible to lay down a general method for the effective construction of any written test, whether it be a termly school exam or a GCSE paper, although feedback to pupils will clearly be of a different order in these two cases. Further, we argue below that such a general method, although initially time consuming, will eventually *save* valuable teacher time while improving the quality of the assessment on offer.

> *To put it in more concrete terms: if you want to build a factory, or fix a motorcycle, or set a nation right, without getting stuck, then classical, structured, dualistic, subject-object knowledge, although necessary, isn't enough. You have to have a feeling for the quality of the work. You have to have a sense of what's good.* That *is what carries you forward. This sense isn't just something you're born with, although you are born with it. It's not just 'intuition', not just unexplainable 'skill' or 'talent'. It's the direct result of contact with basic* reality, *Quality,*

which dualistic reason has in the past tended to conceal. (Pirsig, p. 277-278) **(3.1)**

The method we are suggesting can be briefly expressed as a flow diagram such as the one given below.

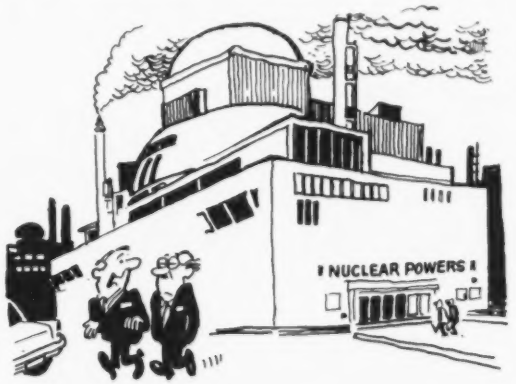
Test setting : a flow diagram


1 List objectives of test and process-skills to be tested.
2 Decide proportional balance between them.
3 List content to be tested.
4 Decide proportional balance of content to be tested.
5 Select question content and question type which best test the process-skills identified.
6 Construct test paper.
7 Convert points 1 and 2 into a detailed marking scheme and check that the paper accurately reflects intentions.
8 Tell those who are to take the test what to expect.
9 Allow the test to be taken.
10 Mark the test papers.
11 Feed the results back to the candidates, including individual detail.
12 Assess test paper to see whether it has met objectives and amend as necessary.

We will now examine each point of the method in more detail, but the reader will be able to see that points 1 to 5, taken together, demonstrate an aphorism beloved of Chief Examiners:

The Mark Scheme should always be constructed before the test paper.

This statement, seeming as it does to contradict sense and certainly to run counter to common practice in schools, deserves a little explanation. How can a mark scheme possibly be constructed before questions are decided? Not surprisingly, its detailed meaning differs a little from the unqualified words in it. As may be seen from the first few boxes in the flow diagram, the first requirement of setting a good written test is to obtain agreement amongst those concerned about what the test is for. Is it to find out whether individuals have grasped the content of the recent module on current electricity or genetics? Is it to find out whether, during that module, they gained the skill of wiring a plug or working out an F2 genotype? Or is it to find out their attitude to the need for generation of electricity on an increasingly huge scale or to research into recombinant DNA?



'A black hole – that's the answer to our radioactive waste problem.'

Chief Examiners usually have these sorts of questions answered for them to a greater or lesser extent. Traditionally, some Examiners have been given little flexibility about content but more about question type. Others are given a carefully-described balance of aims to assess and associated content through which to assess the achievement of those aims. The pioneer of the latter type, and still a good model for those wishing to see how it can be done, was the specification for the SCISP GCE Ordinary level examinations (**3.2**). Much progress has been made in this field over the past dozen or so years, and many of the new GCSE proposals are carefully worked-out examples of this type. (See, for example, the proposals of the NEA (**1.20**) and SEG (**3.3**). Readers wishing to experiment with in-school examinations could do worse than start with a perusal of these recent publications.

To return to the flow diagram and treat it in sequence, it will be seen that we believe the first thing to do is to establish the objectives of the test and the process skills to be tested, in other words, to establish what the test is trying to find out

about those who will take it. Remember, however, that a written question designed to test problem-solving ability for the majority may well be testing recall for one or two candidates! This is but one manifestation of the fact that a class-based teacher can report upon a candidate's level of achievement with far greater confidence than an external examiner. The class teacher bases her or his view on many individual assessments, both formal and informal. The external examiner, on the other hand, has to rely upon the results of a single examination and can normally only report by means of a single grade.

Point 2 in the flow diagram is, however, of equal importance, for a test trying to elucidate attitudes as well as understanding of content will be of little use if it has only one question concerning attitudes tucked away at the end. Many public examination schemes have, in our view, failed this criterion in the past. The classic example is the inclusion of 'social implications of science' in an attempt to show modernity in the syllabus, tested, if at all, by one (optional) question. In fact, this often turns out to be more about whether, for example, the chemistry of the Haber Process is understood.

It is only when decisions 1 and 2 have been taken that the content to be tested can be denoted and the proportional balance of the various content elements decided. However, at this juncture it must be carefully considered whether any element of choice is to be offered within the paper. As a general rule, we believe a choice of questions only clouds the issue and makes it much more difficult to decide on an individual's level of achievement in the various objectives of the test. (Yes, I am a convinced fan of compulsory questions for all; an egalitarian approach for the children as well as a pragmatic one for the teacher, in my view.)

Point 5 of the flow diagram should then follow with little real difficulty, for it is usually obvious which part of the content list and which type of question will be best for testing each objective. Once this point has been reached, the hard/easy part of the process arrives. Constructing a good test paper can *only* be described as 'hard/easy', as will be seen by a perusal of the following four essential parts:

1 finding good ideas for questions which match the decisions made in parts 1-5 *(hard);*
2 writing out the questions from the ideas *(easy);*
3 checking/shredding the questions to be sure that:
   - they are clear and unambiguous to the candidates,
   - they are arranged in a sensible order,
   - there is sufficient, but not too much, room for the candidate to answer them,
   - they can be answered in the time available,
   - they contain no scientific or grammatical howlers and that they simply make sense *(very hard);*
4 getting the papers duplicated and ready in sufficient numbers (*time-consuming, often irritating, but essentially easy*).

Those constructing school-based written papers have advantages, though:

- they can undo the harm done by their mistakes during the feedback process (point 11);
- they can alter the test paper and re-use it (point 12).

The test paper having been set, we reach the point with which much of this Curriculum Guide has been concerned : the importance of the child in the process of assessment. As the SSCR has advocated previously (**0.1**), assessment should be formative and not merely summative. When preparing children for public examinations, the skilful teacher ensures that they are totally aware of the syllabus and the format and style of the papers. S/he then allows practice or 'mock' papers to be taken, under circumstances as close as possible to those which will appertain when the real examination is taken. The papers are then marked (perhaps a little over-severely!) and each child treated to a comprehensive personal dissection of her or his own performance, with emphasis on points needing attention. Improvement of the child's skill at studying is often attempted at about the same time. This scenario, so familiar to readers in the context of CSE/GCE preparation and the like, is much less often observed outside the public examination context. However, it is my firmly-held view that if written assessment is to be used, the time of both teacher and children will have been wasted unless:

- the children have been made totally aware of the purposes of the assessment and the format to be used,
- the assessment is accompanied by constructive feedback to each child.

Points 8 and 11 of the flow diagram thus assume paramount importance where school-based written assessment is concerned. When these objectives are met, written assessment should not be 'threatening'. Rather it should be seen as a device enabling both teacher and child to monitor progress, to identify areas of confusion or incomprehension, and to decide where further work is needed, a device which will provide an encouraging springboard of success for the next piece of work.

Many recently-established schemes also allow the child to decide when s/he is ready for assessment – a further removal of threat. Further involvement can be engendered if children are

simultaneously encouraged to assess their own progress, as in many profiling schemes. Most of the evidence shows them to be exceptionally severe and critical of their own performance!

It is at this point that the final stage in the flow diagram is reached. Rather than construct a totally fresh paper for every occasion, most science departments wisely and pragmatically prefer to re-use papers where possible. In the earlier days of Banda and Gestetner machines, altering part of a paper was awkward, so it was only attempted if absolutely necessary. However, the arrival of the word processor (upon which this Section is being written) has revolutionised the examiner's life! Minor or major changes can be accomplished in very little time and a new printout obtained. Experience leads me to encourage anybody setting a new paper at any level to construct it using a word processor, if this is at all possible.

In conclusion

It is hoped that this chapter will be of use to the many teachers struggling to decide whether to use written assessment or to decide how to improve that which they do use. Within fairly obvious limits, written, summative assessment still has a part to play in the science education of all young people, but it must be properly and sensitively used. However, its limits may not be quite as narrow as is normally perceived. In our view there is scope within the public examination arena, and certainly within the school-based system, for a thorough examination of non-traditional approaches to written assessment. For instance, why not consider:

- getting a *group* of children to tackle a test paper. (This may be a way of assessing an individual's capacity to work with her/his peers.)
- allowing all children to see the test paper a couple of days before taking it. (In what ways would its objectives thereby change?)
- allowing children to consult any books or other resources they wish to during the course of the test. (Objectives will change again!)

It is by considering such changes of approach, as well as by careful consideration of the purposes of written assessment, that its role in science education will become both more defined and more refined, to the benefit of both teacher and pupil.

SECTION FOUR

An overview

Assessment is clearly a very important aspect of the teaching and learning process. As will be immediately apparent from the catalogue of development work reviewed in earlier chapters, assessment is also an increasing preoccupation for many teachers, and the introduction of GCSE has put a number of issues into sharp focus. This Curriculum Guide has attempted to illuminate some of the current issues, concerns and terminology and to set these within a framework of Review principles, policies and ways of working. Our intention has been to inform and to influence practice in laboratories and classrooms. 'How do we measure up?' is a legitimate question for the reader, and setting in hand a review of the school's and/or department's assessment patterns and strategies is a useful step towards an answer. Such a fresh look might well lead to short-term improvements in existing practices and procedures, and in the longer term to changes in policy. It may also point out training and development needs.

Beyond such a review, we would also wish to encourage departments and individuals to know about and to seek to influence trends and developments. Involvement with other teachers, with professional associations and with the syllabus and research committees of examining boards and groups all represent valuable ways of 'keeping in touch'. Well-informed teachers and departments are better able to deal effectively with the interests and concerns of parents, employers and the wider community in assessment matters, and we know all too well that such concerns exist.

In short, we have attempted through this Curriculum Guide to promote and encourage an active and developing view of assessment which recognises both its real potentials and its hazards and pitfalls. Towards this end, the following set of recommendations are offered as a further stimulus to discussion and policy formation. (The list is in no way hierarchical, nor does it represent a sequential programme for a review process.)

Recommendations

We recommend that:

1 assessment be recognised as a valuable formative tool and that policies are implemented which allow it to be used in this way.
2 before embarking upon any assessment procedure, careful thought should be given to the purpose of the assessment.
3 recognition, and considerable attention, be given to the sorts of assessment to which youngsters have been subject prior to entering secondary school.
4 the potential of assessment for developing a positive self-image in the student should be recognised.
5 the outcomes of assessment should be used to modify both teaching methods and the curriculum and not simply to indicate the progress of the student.
6 a well-thought-out policy should be adopted which improves the construction, marking, and usage of summative tests.
7 just as the utilisation of a greater range of teaching and learning strategies improves the quality of science education, so will the adoption of a wide range of assessment styles, carefully chosen so as to reflect the curriculum.
8 the assessment policies adopted by a school science department should reflect the school policy on such matters. (There may be a case, however, for the science department initiating the assessment review!)
9 consideration be given to the extent to which the assessment of students' attitudes to science (both in curriculum and more general terms) should be departmental assessment policy.
10 consideration should be given, in any piece of assessment, to the desirability, or otherwise, of moving from norm-referenced towards criterion-referenced assessment.
11 assessment results should be reported in ways which maximise their usefulness for the student, other teachers, parents, employers and other educational establishments.
12 assessment in science should become part of a profile which students gradually build up over their school career and to which they themselves make a substantial contribution.
13 microcomputers should be used to minimise the extra administrative burden which better assessment brings.
14 recognition be given by government, LEAs, head teachers, governors and teacher unions to the time and resource implications of better assessment and due allowance be made for this in the construction of the working day of all teachers.
15 all assessment in science should be constructed so as to give students positive feedback and a feeling of success which will encourage them to proceed further with their studies.
16 summative testing should move in the direction of establishing what children *can* do, rather than what they cannot, and that such testing should always utilise the top thirty per cent of the mark range as well as the bottom seventy per cent.
17 the teachers in a science department should use a common framework for the marking and grading of work, which is fully understood by the youngsters, their parents and themselves.
18 wherever possible, assessment procedures should have an element of self-assessment by students of their own performance and the areas in which they need help or need to work harder.
19 assessment by the young person should result, as soon as possible, in an evaluation of the curriculum on offer and of the teaching and learning process.
20 each science department should select for its use only those GCSE courses which permit the gradual adoption of the above policies.

We are aware that readers will already be implementing some of these ideas and that a few of the recommendations are aimed at those in a position to influence the allocation of resources, including the important resource of time. However, unless we give careful thought to these issues, make ourselves fully aware of new strategies and can argue our case with conviction and supporting evidence, we will find it more difficult to influence those who make decisions in the light of many competing claims.

As in all other matters relating to science education, departments working together will be more effective in exerting influence than individuals can be. Furthermore, the recommendations are equally applicable in other subject areas. We see our list as a stimulus to individual review, to departmental review, to inter-departmental discussion and, ultimately, to whole school policy review. In this respect, we make no apology if we appear 'evangelistic'.

We would end, however, with two reminders. First, it is important that parents, employers and other users of the outcomes of our assessment programmes not only understand our reports and find them useful but also have some understanding of our processes and purposes in undertaking the assessment. We must take time to explain these fully. Second, we believe that the student is central to the assessment process – as an active participant with some control and a contribution to make to the assessment programme in terms of its nature, its timing and

the use to which its results can be put. The development of positive self-image and the skills of self-assessment are of life-long value. We must endeavour to produce assessment programmes that help our students acquire these qualities.

APPENDIX I

Graded assessment in science schemes

Each of the graded assessment schemes listed in Section 2 has its own special features and its own special character. In this appendix, we will attempt to highlight these.

The Avon Science Achievement Scheme

This has a relatively simple two-level structure and was developed for the post-13 cohort below the 60th percentile of the ability range. Mastery is defined in terms of 60-85 per cent success leading to a silver award and over 85 per cent leading to a gold award. Further details may be obtained from
The Senior Adviser (Mathematics, Science and Technology)
The Education Department
Avon House North
St James Barton
Bristol BS99 7EB.

The ILEA Scheme (Graded Assessments in Science)

This has a three-dimensional framework covering content, process-skills and explorations. It is appropriate for the full ability range and the 11–16 age range and thus has a somewhat complex system of levels and tiers of difficulty. The aim is for levels 10–15 of the fifteen-level structure to have GCSE equivalence but special Statements of Achievement of the University of London Board are being awarded on the basis of success in all three dimensions at all the lower levels. The Explorations dimension, based on both practical and theoretical investigations, serves the dual function of bringing together the content and process dimensions by providing the youngsters with opportunities to tackle real problems and introducing them to the imaginative and creative aspects of science. This aspect of the scheme is particularly interesting and well developed, and has much to recommend it. Further details of GASP can be obtained from
Room 3.227, King's College (KQC)
552 Kings Road
London SW10 0UA.

The Oxford Certificate of Educational Achievement

This is a package of three inter-dependent components of which the graded assessment (G) component is just one. (The graded assessment schemes cover a number of subject areas.) The other components of the Certificate are the personal (P) component and the external qualifications (E) component. A problem-solving approach is used in the G component for science, and there is a breakdown of problem-solving into four processes covering two or three component skills. No content is specified, the skills and processes of science being the focus of the assessment. There is no direct link of the G component for science to GCSE. The science education programme is expected to provide opportunities for development of some of the social and personal skills of the P component. Further details are available from
The Oxford Delegacy of Local Examinations
Ewert Place
Banbury Road
Oxford OX2 7BZ.

MEG Assessment of Graded Objectives

Again this is a scheme developed for the full ability range and the 11–16 age range. There are nine levels of achievement, covering three stages. The Introductory Stage (Levels 1 and 2) is strongly process-orientated and there are suggested activities for development of skills. The Foundation Stage (Levels 3 and 4) sees the introduction of modules of essential content but continues the development of skills assessment across three domains including knowledge and understanding as well as process. The Extension Stage (Levels 5–9) covers a wider range of content and will have GCSE equivalence with single and double science awards. Separate science awards may be possible in the early period of operation. There is a strong process orientation throughout. Further details may be obtained from
The Midland Examining Group

Syndicate Buildings
1 Hills Road
Cambridge CB1 2EU.

The TAPS Project

As already explained, the TAPS Project is not a graded assessment scheme. It has been developed in Scotland, it is criterion-referenced and it provides the teacher with information on a student's progress in key areas of the science curriculum. As in the graded assessment schemes outlined above, the compilation of student achievements in six basic skills areas, all practical, is achieved through internal assessment conducted by the teacher. The assessment in these six areas counts towards national certification at Foundation Level.

By a 'step-up' approach, opportunites to display process skills such as 'selection of procedures' and 'skills of inference' are later added. These contribute to the summative assessment at General Level. Investigative skills are encouraged through students going on to tackle scientific investigations. In its early stages of development, the scheme was criticised for its atomistic approach, but later work relating to the development and assessment of process skills and the synthesis of these in the execution of problem-solving explorations has gone some way to answering these criticisms. Further details are obtainable from
The TAPS Unit
Room 317b
Jordanhill College of Education
Southbrae Drive
Glasgow G13 1PP.

APPENDIX II

Pre-vocational and other developments

Developments pre-16

Early in 1985, a DES working party, serviced by the SEC, was established to prepare criteria for pre-vocational and vocationally-orientated examination courses offered to students still in compulsory secondary education. The working party included representatives from a wide range of interested organisations, including the City and Guilds of London Institute and the Business and Technician Education Council. In September of the same year, CGLI and B/TEC announced plans for a new pre-vocational curriculum for 14–16 year olds, to start in September 1987. Initially this is to be geared towards students taking TVEI courses but it is planned that the new qualification will develop to cover broad, modular courses which link with the Certificate of Pre-Vocational Education post-16 and lead on to further educational qualifications or the Youth Training Scheme. Existing B/TEC preparatory programmes and CGLI Foundation and 365 courses will be replaced with a new framework on to which students might add GCSE subjects. It is emphasised that the new qualification will meet the needs of students following courses which are complementary to, rather than competing with academic courses. From the SSCR viewpoint, encouraging features of the proposals are that they include the use of student records of achievement and that they are designed to match with more flexible, cross-curricular approaches to learning. Provided that the approach encouraging the free mixing of pre-vocational and academic components is maintained, criticisms that there is an implied division at 14+ into academic and non-academic education should be allayed.

Developments post-16

Developments post-16 are many and various, including the pre-vocational/vocational and the academic. There is only room here to consider them in a superficial manner.

Pre-vocational/vocational qualifications

The Certificate of Pre-Vocational Education provides a curriculum framework for a one year (currently) programme of study. It has been developed for students drawn from the full ability range who decide to stay in full-time education, whether in school or in college, but who neither wish to take A levels nor follow a purely vocational course. CPVE proposals stipulate a *unified* course based on three main elements:

1 core studies, covering ten curriculum areas, of which science and technology is one;
2 vocational studies, including planned work-experience (which may be simulated work-experience);

3 additional studies, intended to meet the varied needs of the CPVE cohort.

Centres, which may be individual schools or colleges or consortia of both, devise their own courses which have to be validated by the Joint Board for Pre-vocational Education. The emphases of the courses are on experiential learning, integration of the course elements, and involvement of the students in the planning, organisation and assessment of their own learning. The assessment scheme is an externally moderated one, which is criterion-referenced and emphasises the formative as well as the summative purposes. It will cover both core and vocational studies. The design of the formative assessment procedures is the responsibility of the Centre, but these procedures are monitored by the Joint Board. The Board has developed national criteria for assessment of all ten core areas. Centres assess student achievements against these national criteria using a variety of procedures designed to reflect the learning programmes. All those completing the course receive a certificate containing a profile of experience and achievement during the course.

There is little evidence at this stage that this complex development with its novel features relating to structure, organisation and assessment is in any way coordinated with GCSE developments. Its philosophies appear to match those of the SSCR, but it has to be admitted that problems over implementation have been experienced with the first cohort of candidates. The above account should be regarded as purely descriptive, with no element of analysis or criticism.

The National Vocational Qualification is a proposed single, but multi-level, national qualification to encompass all existing vocational awards. It is the key recommendation of the *Review of Vocational Qualifications* published in 1986, which calls for a tighter and more coherent structure of vocational qualifications and recognised arrangements for specifying standards of competence. It is intended that YTS should fit into the five level structure, but whether there will be a place for CPVE at the first level of the qualification is not clear.

It is to be hoped that there will be dialogue between the new National Council for Vocational Qualifications and the Secondary Examinations Council.

Academic qualifications

Common cores for A-level courses have been agreed and introduced by the examining boards although these are now in need of further consideration in the light of developments at 16+ and in particular the growth of broad, balanced science courses leading to a double science award.

A new system of A-level grading will come into effect for the examinations in the summer of 1987 which should overcome the problem of a very few percentage points separating those candidates achieving a grade B and a grade D, with all the implications that this has had for entrance to higher education. It may also start the process of searching for criteria at some A-level grade boundaries.

The development of AS levels (to be introduced in 1987 with the first examinations in 1989) is a more interesting one. While the time-table for their development and introduction so soon after GCSE gives cause for concern, the principle of broadening the studies of sixth form students which is implicit in the development of AS levels is to be welcomed. An AS level will be equivalent to 'half an A level' in content and time terms, but equivalent to a full A level in terms of standard. AS levels will be categorised as either complementary or contrasting. Complementary syllabuses are intended for students wishing to broaden their studies within their chosen area of the curriculum. Thus a student following A-level courses in chemistry and mathematics may complement these with AS levels in physics and biology. Contrasting syllabuses are intended to provide a much greater breadth of study, with the AS level subjects being drawn from very different areas of the curriculum. Given the often stated need for greater public understanding of science (in a general sense), it is surprising that a Science AS level was not among those recommended by the Secretary of State for priority development.

When the idea of AS levels was first proposed, there was considerable concern among teachers about the acceptability of these new qualifications in relation to admission to further and higher education. It is very encouraging to note that both the Standing Conference on University Entrance and the Council for National Academic Awards have announced their acceptance of AS levels for entry purposes. It is hoped that this acceptance of AS levels is the first of a series of moves which will result in the type (and combinations) of qualifications leading to admission to higher education being broadened yet further.

Glossary

Assessment objectives The target of the assessment. Skills and abilities that are measured and recorded for assessment purposes, expressed in terms of observable and measurable behaviour which the achievement of the educational aims of a course is intended to bring about.

Criterion-referenced assessment Assessment which is undertaken with reference to predetermined standards. The assessment provides information about specific knowledge and abilities of candidates without reference to performance of others (cf. norm-referenced assessment).

Differentiation Process by which different levels of performance can be measured. Differentiation may be achieved by setting questions at different levels of difficulty to match levels of attainment in candidates or by setting common questions which will be marked according to degree of thoroughness and sophistication of response.

Discrimination Index of the power of a test item to distinguish between candidates with different levels of performance.

Domain A collection of elements of a subject forming a coherent sub-set of skills and competences (a cluster of foci for assessment).

Facility A measure of the ease with which a test item can be answered. (The facility index has implications for the discriminating power of a test item.)

Formative assessment Assessment undertaken during a course which is designed to provide information about progress (in key areas of work). Assessment made with a view to prompting remediation and hence bringing about improvement.

Graded assessment Assessment by means of which candidates are given credit in stages for what they can do.

Grade description Description of the level of attainment expected at a particular grade in positive (and subject specific) terms.

Grade related criteria Specification of the range of skills and competences which candidates must achieve to be awarded particular grades (within an assessment scheme as a whole or within a domain).

Limited grade syllabus A syllabus for which it is recognised that the full range of grades cannot be awarded. The proposal may not fulfil the full range of content and/or skills and/or activities required in that subject by the examination board, in terms of syllabus and/or scheme of assessment.

Moderation The process of producing conformity of standards (as far as is possible) between different centres, different assessors and examiners or different assessments/examinations.

Norm-referenced assessment Assessment whereby the standard of performance is based on comparisons between candidates (with no absolute standards of performance).

Profile Document or record presenting information (without indication of level of achievement) about an individual's experiences and performance over a range of skills and competences.

Reliability Measure of item to item consistency within a test, or measure of reproducibility of the results of an assessment.

Summative assessment Assessment carried out at the end of a course or topic designed to measure level of attainment.

Validity The accuracy with which a test measures that which it intended to measure, as defined by the test objectives. (For definitions of different types of validity see Fairbrother, R.W.(1986) in Nellist, J. and Nicholl, B. (eds) *The ASE Science Teacher's Handbook.)*

Weighting The relative contribution that a particular component of an assessment makes to the aggregated whole.

N.B. The reason why the terms 'skill' and 'process' are not included in this list, although the Central Team 'defined' them in their publication *Towards the Specification of Minimum Entitlement: Brenda and Friends,* is that there is a wide variation in the way in which these terms are used in the literature. Almost every SSCR group using the terms has used them in a different way.

Further reading

Black, H.D. and Devine, M.C., *Assessment Purposes: A Study of the Relationship between Diagnostic and Summative Assessment for Certification*, Scottish Council for Research in Education, Edinburgh, 1986
This booklet sets out to explore some of the issues which arise from the need for assessment to serve both formative and summative purposes, with the aim of providing guidance for teachers when designing their own assessment strategies.

Brown, S., *What Do They Know? A Review of Criterion-referenced Assessment*, Her Majesty's Stationery Office, Edinburgh, 1980
A report of a detailed study on criterion-referenced testing conducted on behalf of the Scottish Education Department.

Brown, S. and Munn, P. (editors), *The Changing Face of Education 14 to 16: Curriculum and Assessment*, NFER/Nelson, Windsor, 1985
The changes described in this book, having its context in the Scottish education system, have major implications for all teachers, curriculum developers and examiners. It covers criterion-referenced assessment, diagnostic assessment, certification for all, mastery learning, etc., and contains discussion of issues that are central to the current debate on curriculum and assessment.

Bryce, T.G.K. and Robertson, I.J., *What Can They Do? A Review of Practical Assessment in Science*, Studies in Science Education 12, 1985
A reviewer of this publication writes 'This (major article) is an authoritative review of practical assessment in science – surely obligatory reading as the onset of GCSE approaches.'

Frith, D.S. and Macintosh, H.G., *A Teacher's Guide to Assessment*, Stanley Thornes, Cheltenham, 1984
This book provides the reader with a clear understanding of the main techniques of assessment (and their pitfalls). Its three main sections deal with purposes and objectives, techniques of assessment and the reporting of the information obtained through assessment. There are a number of case studies and an extensive selection of self-teaching exercises.

Harlen, W., *Guides to Assessment in Education: Science*, Macmillan Education, London, 1983
Although this book is concerned with assessment in primary and middle schools, it has much to recommend it to the secondary-based teacher. It discusses the essentials of teaching and learning in science in (primary) schools and the development of appropriate methods for measuring progress. Emphasis is placed on providing classroom examples matched to modern research, but in a relatively untechnical manner.

Kempa, R., *Assessment in Science*, Cambridge University Press, Cambridge, 1986
This is an authoritative and up-to-date account of current assessment and examination procedures, which discusses the relationship between assessment in general and the aims and intentions of science education. Current trends and future developments are also considered.

Macintosh, H.G. (editor), *Techniques and Problems of Assessment*, Edward Arnold, London, 1974
Although written some time back, this book provides a valuable overview of the assessment techniques of the time, their advantages and disadvantages, and with its practical bias will be of help to teachers.

Mathews, J.C., *Examinations: A Commentary*, George Allen and Unwin, London, 1985
This book deals with four main aspects of examinations: their context, their function, their equity and their future. It highlights the twin tensions between the need for common national standards and the need for diverse individuality, and between the function of examinations as instruments of selection and the descriptive function of records of achievement and progress.

Mobley, M., Emerson, C., Goddard, I., Goodwin, S. and Latch, R., *All about GCSE*, Heinemann Educational Books, London, 1986
Brought together in this book is a careful, balanced and readable account of the many aspects of GCSE. Each chapter deals with one topic and attempts to answer the questions that will arise in the minds of teachers, parents and employers.

Nellist, J. and Nicholl, B. (editors), *The ASE Science Teacher's Handbook*, Hutchinson, London, 1986
In Chapter 4 of this book, which brings together many important aspects of science teaching today, the topic of assessment and examinations is explored thoroughly by Bob Fairbrother.

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The Secondary Science Curriculum Review (SSCR) was set up in 1981 to stimulate, through working groups of practising teachers, the development of science studies which would help to provide an appropriate science education for *all* young people growing up in a scientific and technological society — whatever their abilities or career intentions. Its concern was not only with the science curriculum — its contents, purposes, teaching methods and resources — but also with the role of science in general education and within the whole school.

The **Better Science: Curriculum Guides** are based on the combined experience of the Review's Central Team and the working groups. Each Guide deals with a different but significant area of concern. Together they aim to assist teachers both in devising a broader and more balanced approach to science studies and in enhancing their professional development. The intention throughout is not necessarily to provide answers but rather to provoke and encourage teachers' thinking about the various topics addressed.

This Guide, **Better Science: Assessing progress,**

- aims to raise key issues concerning assessment;
- provides a measure of up-dating with regard to development both inside and outside the SSCR;
- encourages science teachers and departments to reflect on their current practice;
- is set in the context of the Review's belief in the need to change the emphasis towards formative, criterion-referenced assessment with greater involvement of the young person.

ISBN 0 435 54821 2

Also available:

Better Science: A Directory of Resources contains details of a broad range of materials produced by local working groups and the Review's Central Team. It includes descriptive and evaluative statements on each piece of material listed.

Better Science: Making it happen summarises, for a wide audience, the thinking of the Review and provides a guide to implementing balanced science for all pupils.

Heinemann Educational Books/Association for Science Education for the School Curriculum Development Committee

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